CORRELATION BETWEEN MOLECULAR LINES AND DIFFUSE INTERSTELLAR BANDS

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Observations are presented of the Diffuse Interstellar Bands (DIBs) at 4726, 4763 and 4780 Å and at 5780 and 5797 Å together with the ultraviolet lines of CH and CN molecules for stars with different shapes of the UV extinction curve. We discuss new results concerning the relationship between different characteristics of the interstellar clouds: molecular lines, blue and yellow DIBs, and the UV extinction curves.

Introduction

The first applications of high signal–to–noise spectra to the problem of DIBs have shown the feature ratios are variable from sightline to sightline (Krełowski and Walker, 1987; Josafatsson and Snow, 1987; Krełowski and Westerlund, 1988; see also Herbig, 1993). Subsequently, for the first time on the basis of uniform spectroscopic observations, Sneden et al. (1991) have shown that the strength ratios of the yellow DIBs at 5780 and 5797 Å depend on the shape of the extinction curve determined along the same lines of sight. The latter have been segregated into three families: "zeta" – named after ζ Per – characterized by the broad 2200 Å bump and the significant far–UV rise of the extinction curve and showing the depth ratio of 5797/5780>1; those ones with extinction law similar to that of σ Sco ("sigma" family – strong 2200 Å bump and the flat far–UV segment of the extinction, the 5780/5797 DIB depth ratio <1); while the peculiar Be–family (lack of the 2200 Å feature) shows much weaker DIBs than in any other case. This segregation is also seen based on the sharp features of simple interstellar molecules (CH and CN). They are observed in spectra of stars obscured by ζ–type clouds and are below the level of detection in the σ–family (Krełowski et al., 1992).

Observations

The observational project reported here concernes the above mentioned molecular features as well as the relatively weak blue DIBs at 4726, 4763 and 4780 Å. Since their discovery by Herbig (1975) they have been observed only twice with the aid of solid–state receivers (Krełowski (1989), Jenniskens and Désert (this meeting)). The goal of our project is to check whether clouds characterized by very different extinction curves also show systematic differences among weak blue DIBs as they do in the case of strong 5780 and 5797 yellow DIBs. The spectra of HD 149757 and HD 2905 (see Krełowski, 1989), closely resembling "zeta" and "sigma" cases, may suggest so. These objects, having similar E(B–V), show the 4726 band at comparable strength, while the two other blue DIBs are evidently weaker for the ζ case.

High resolution observations with the Coudé Spectrograph of the 1.2 m telescope at the Dominion Astrophysical Observatory have been performed in the spectral range covering molecular features of CN and CH (from about 3855 to 3900 Å) and recorded on the RCA 1000 x 1000 CCD detector.

Table 1: Basic data for programme stars

HD number	E.W. [mÅ] 5780	E.W. [mÅ] 5797	depth 5780	depth 5797	mol. lines	E(B−V)	4726	4763	4780
				ζ family					
23180	(78)[a]	(58)[a]	(0.039)[a]	(0.077)[a]	Y	0.26			
149757	68	31	0.033	0.037	Y	0.29	Y	Y	Y
				σ family					
22951	89	35	0.043	0.040	N	0.23	Y	Y	Y
224572	67	17	0.032	0.020	N	0.16	Y	Y	Y
				Be family					
10516	65	12	0.033	0.015	N	0.19	N?	Y	Y
202904	36	4	0.019	0.007	N	0.10	N?	N?	Y

[a]Krełowski et al. (1992)

The mosaic grating composed with the "long" camera gave a dispersion of about 2.4 Å/mm. In the spectral range of blue DIBs (from about 4723 to 4791 Å) the Reticon silicon diode array of 1872 elements was applied. Both detectors are characterized by the pixel width of 15μm along the dispersion axis which gives linear resolution of about 0.07 Å/pixel. The observations were carried out in September/October, 1992 by two of us (JK and ETK).

The observations of the same targets with the same resolution and high signal−to−noise ratio, covering the spectral range of the yellow DIBs at 5780 and 5797 Å have been obtained with the Cassegraine Echelle Spectrograph installed at the McDonald Observatory 2.1 m telescope by two of us (JK and CS). Observations were carried out during three observing periods in February, May and November 1993. Deatils can be found in the paper by Krełowski and Sneden (1993).

Discussion

In Table 1 we list our targets divided into three "families" (the selection and segregation was based on the shape of vacuum−UV extinction curves published by Papaj et al., 1991), providing the basic data for them (E(B−V)'s are taken also from that paper) and some information about the observational results. The UV extinction law – typical for each family – is shown in panel (a) of the Figs.1−3 for ζ, σ and Be−families, respectively. In panels (b) near−UV ranges with spectral features of the CN and CH molecules are shown, in panels (c) the observed yellow DIBs, while in panels (d) the observed blue DIBs. The y−scales used for diagrams shown in panels (a), (c) and (d) are the same, allowing the immediate comparison between the presented characteristics of different families.

As can be seen from panels (c) of Figs.1−3, a relation between extinction laws and the yellow DIBs is confirmed by these new observations. The measured equivalent widths, as well as central depths, of the two yellow DIBs at 5780 and 5797 Å are listed in Table 1. The 5797 DIB seems to be more sensitive to the observed changes of physical parameters of intervening clouds (see Table 1).

Panels (b) demonstrate clearly that sharp molecular lines of CN and CH are seen only in the case of ζ−family (marked by Y in column "mol. lines" of Table 1). They are not seen (N in the same column of Table 1) either in the case of members of σ−family (as shown by Krełowski et al., 1992), or in the case of stars belonging to Be−family.

The blue DIBs (panels (d)) are much weaker than the yellow ones and low signal−to−noise ratio does not allow quantititative mesurements of the observed bands. Qualitatively, it is clear that in

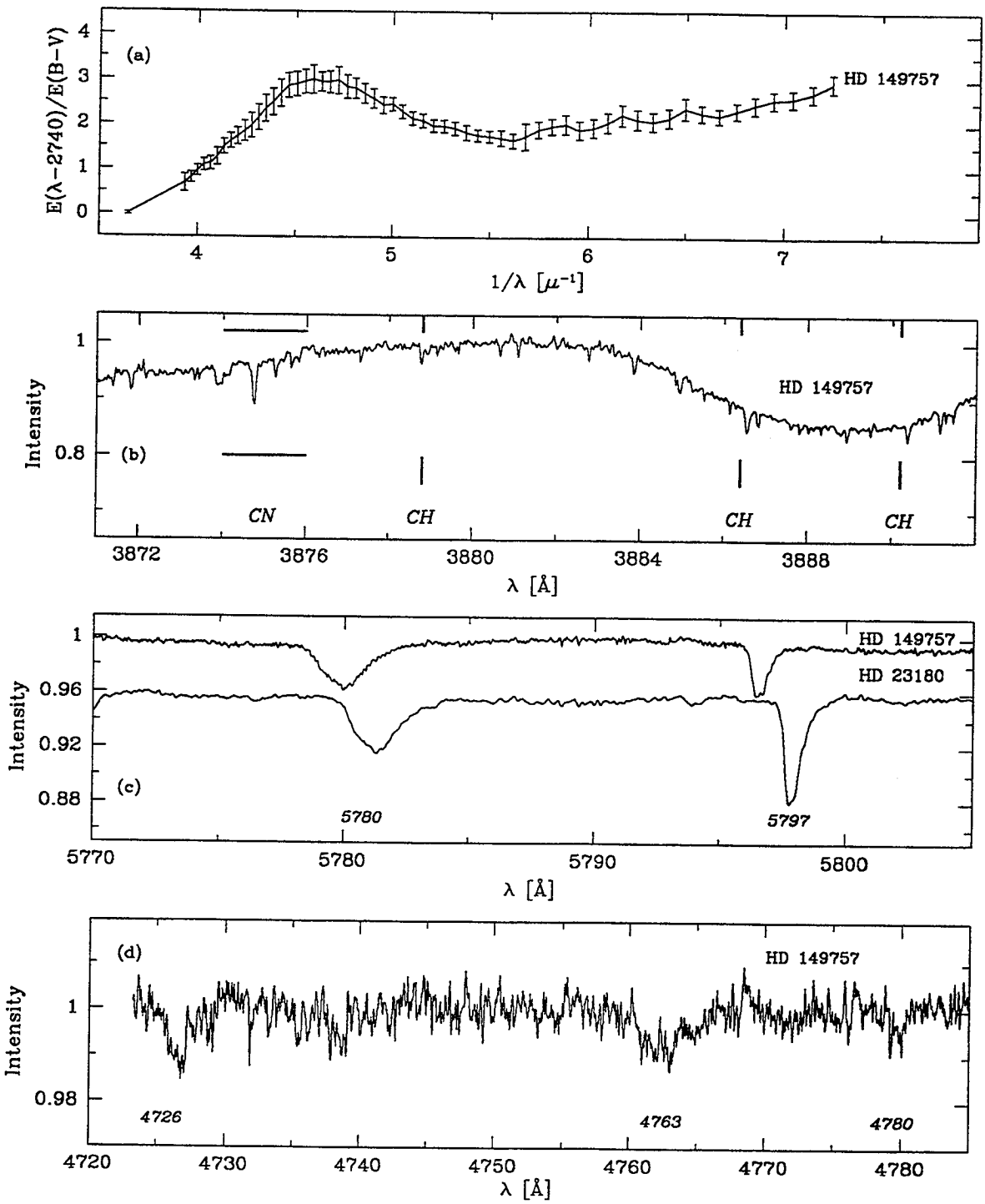

Figure 1: Observed characteristics of the target stars belonging to ζ−family: (a) typical ζ−like UV extinction curve based on TD−1 spectrum; (b) near−UV spectra with marked positions of the CN and CH features (note the sharp features of these molecules observed in the spectrum of HD 149757); (c) the 5780 and 5797 yellow DIBs; (d) the 4726, 4763 and 4780 blue DIBs.

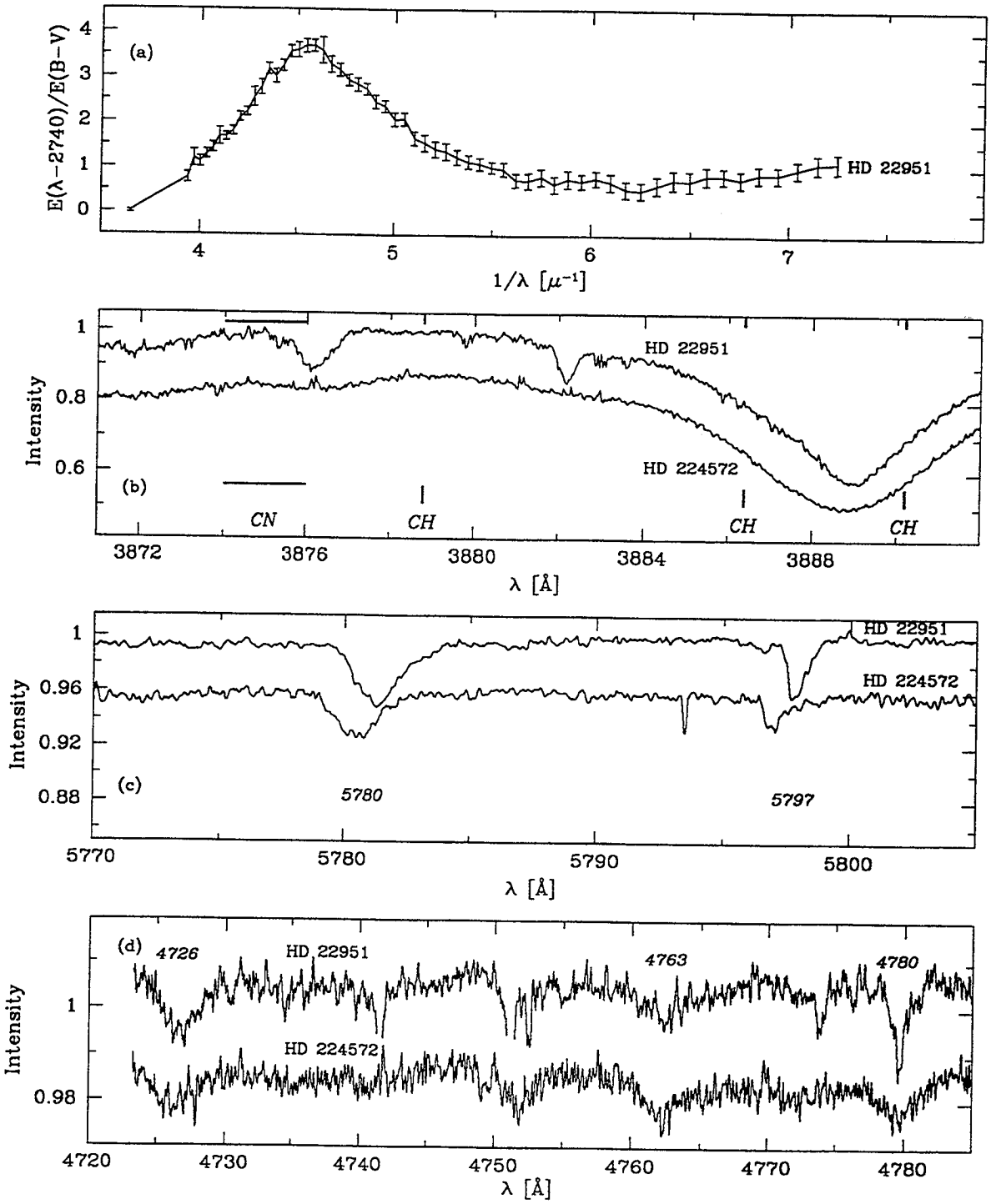

Figure 2: Observed characteristics of the target stars belonging to $\sigma-$family: (a) typical $\sigma-$like UV extinction curve based on TD−1 spectrum; (b) near−UV spectra with marked positions of the CN and CH features (note the lack of these features in the $\sigma-$family); (c) the 5780 and 5797 yellow DIBs; (d) the 4726, 4763 and 4780 blue DIBs.

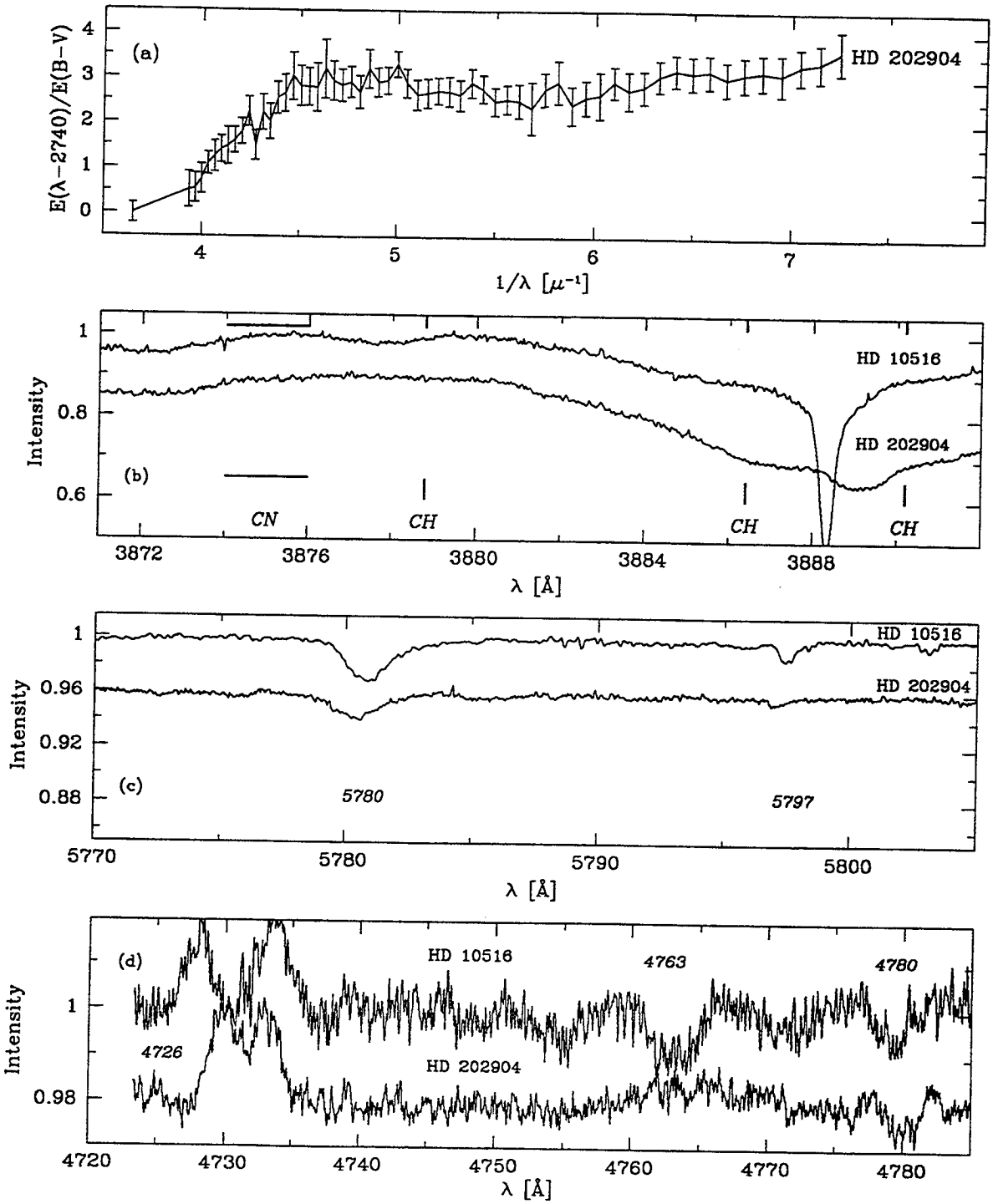

Figure 3: Observed characteristics of the target stars belonging to peculiar BE–family: (a) peculiar "bumpless" UV extinction curve based on TD–1 spectrum; (b) near–UV spectra with marked positions of the CN and CH features (note the lack of these features for members of this family); (c) the 5780 and 5797 yellow DIBs; (d) the 4726, 4763 and 4780 blue DIBs.

the case of stars from ζ and σ–families, these DIBs are present (Y in the columns 4726, 4763 and 4780 of Table 1) and that the 4726 band seems to be strongly correlated with E(B–V) as it is the case for the yellow 5797 DIB. However, it seems that we are not able to confirm the suggestion of Krełowski (1989) that for the ζ–family the 4763 and 4780 bands are weaker than for the σ one in relation to E(B–V). The blue DIBs for the stars from Be–family (see panel (d) in Fig.3) are the most confusing: it is difficult to say if the 4726 one is seen at all (probably because blending with the stellar emission line at about 4730 Å – we marked this uncertainty by N? in the respective column of Table 1), while the 4763 and 4780 bands in the case of HD 10516 seem to be at least as strong as in the spectra from panel (d) of Figs.1 and 2. The case of HD 202904 seems to be "peculiar": having 4780 band of the comparable depth as in HD 10516, it is difficult to say that we see band 4763 at all (N? in the respective column of Table 1).

We find our sample insufficient to infer some definite conclusions concerning the behavior of weak blue DIBs as well as molecular features towards the targets representing different cases. As suggested by Krełowski and Seab and also by Wegner and Krełowski (this meeting) DIBs are either weak or absent in circumstellar shells (their E(B–V) is limited to ~0.3). However, molecular features have already been found in ζ–type clouds producing similar reddenings. Thus the simple molecules, as well as DIB cariers, seem to be not abundant in the environments of circumstellar disks.

Conclusions

The analysis of our observational data confirms the earlier suggestions that the intensity ratios of diffuse interstellat bands are related to the shape of extinction curve. Diffuse bands are likely to be observed in the spectra of most reddened stars even in cases of low reddenings. Their ratios are sensitive to the shape of extinction curve and do not depend on the color excess in any simple fashion.

The DIB carriers can easily survive the harsh conditions of diffuse interstellar clouds, which are easily penetrated by energetic ultraviolet photons. On the other hand they are seemingly scarce or absent in circumstellar shells, perhaps because of sticking to grain surfaces in a collapsing cloud or forming big aggregates not capable of producing spectral features known as diffuse bands.

The simple molecular species are observable only in quite rare cases. Their intensities (or presence) are not apparently related only to the shape of the extinction curve, but a threshold effect of E(B–V) may also be suggested. The spectral range containing CH and CN lines should be observed with high resolution to find possible relations to other interstellar absorptions.

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